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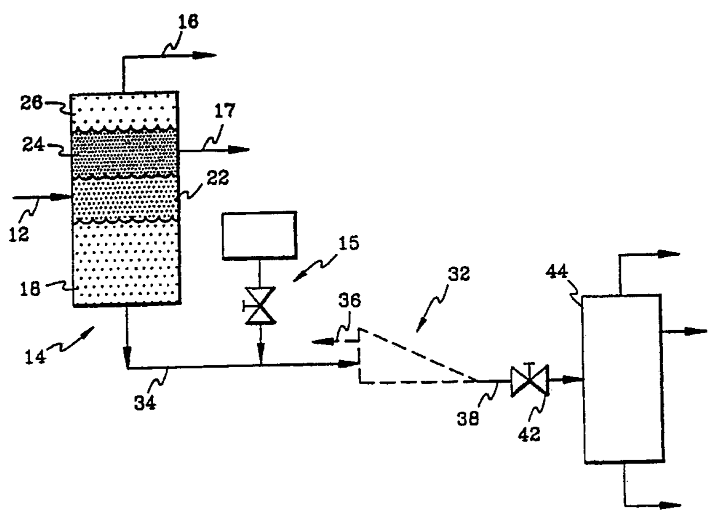

(57) Abstract

A technique for predicting the performance of a hydrocyclone separation process (32) involves taking of a mixture sample from a flowstream (34) under actual separation operating conditions, having the same physical and chemical characteristics present in a hydrocyclone. The sample is centrifuged (14) for a period of time and at an RPM which will simulate the combined effect of centrifugal force and residence time that the mixture would be subjected to under actual operating conditions in the hydrocyclone (32). A separation modifying agent can be injected (15) upstream of or at the sampling point (54) to provide a prediction of its effect on the separation process. After centrifuging (14) the sample, an analysis of one of the phases of the sample is performed to determine the degree of effectiveness of the simulated separation. This result is directly comparable with that expected in the actual separation performed using hydrocyclones (32).

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METHOD AND APPARATUS FOR PREDICTING HYDROCYCLONE PERFORMANCE

Background of the Invention

It has been a problem in the past to determine the applicability of a hydrocyclone separator to a particular fluid separation process. This is especially the case where the fluids being separated have specific characteristics that are peculiar to the process location, as is the case, for example, in oil/water separation associated with oil production. Because of the wide range and varieties of mixtures to be separated and the physical parameters imparted to those mixtures by the formation characteristics as well as the variety of oil field production processes, it has proved difficult to model all the variables involved to predict how a hydrocyclone separator would perform for a given set of conditions. In oil field applications, such predictions have in the past been focused on droplet size information. This variable is known (by Stoke's Law) to have a predominant effect on any gravity separation device, such as a hydrocyclone. However, other numerous factors such as, for example, temperature, pressure, viscosity, chemical constituency of the mixture, turbulence in the flowlines, etc., have made any simple analytical solution laborious. Since hydrocyclone separation equipment is costly, it is imperative to provide some factor of predictability in order to convince an operator to invest the funds necessary to install the equipment.

Recently hydrocyclone separators have found increased usage in separating oil from water on offshore platforms. In a typical oil well production operation, especially the amount of produced water increases as the field matures. In some operations, the bulk of the volume of produced fluids may be water. Although there is sometimes no direct economic incentive, recent tightening of government regulations in various parts of the world regarding the amount of oil that can be present in water discharged into the ocean has increased interest in improving and optimizing oily water separators.

This problem is particularly acute on offshore production platforms. Size and weight limitations on separation equipment limit

the available options. Furthermore, on floating offshore platforms, the movement of the platform may affect the performance of some traditional types of separating equipment.

The most traditional scheme utilized for cleanup of oily water on offshore production platforms includes a weir type primary separator which allows the oily water to stand for a period of time such that free oil can accumulate at the top thereof and pass over a weir, with the cleaner stream then being drawn off from the primary separator and directed to a flotation type secondary separator. The flotation type secondary separator is very large, on the order of the size of a large room, and is motion sensitive. A level control valve is disposed between the primary and secondary separators and is operably associated with a level sensing device in the primary separator to account for varying input flow and to maintain the appropriate fluid level in the primary separator. Such systems are reasonably easy to model in order to predict their operability.

As offshore fields mature and the volume of water production becomes greater and greater, traditional systems like that just described become less and less practical. Furthermore, the motion sensitive nature of the secondary separators utilized are particularly unsuitable to floating platforms such as tension leg platform designs which have come into use in recent years.

More recently, the use of hydrocyclone separators as a substitute for the flotation type secondary separator have been proposed, and are now in service for this purpose. In any proposed application of separation systems to a particular process, some method or technique must be used to estimate the performance of the proposed system. Such estimating techniques include: (1) Stoke's Law approximations, (2) droplet size correlations, and (3) pilot tests using the separation equipment. In the first case, Stoke's Law may be used to crudely estimate the separation in a hydrocyclone. This requires making an assumption about the droplet size distribution. The second method uses droplet size measurements and oil concentrations to

predict hydrocyclone performance based on previous performance results as is disclosed in U.S. Patent 4,844,817. However, when predictions are made on systems with different temperatures, chemical constituencies, and densities, the predictive results can lead to disastrous errors. The third method is to actually build a small scale separation unit. The small scale or pilot unit must meet the codes and inspection requirements of the processing equipment which will eventually be used. Additionally the installation cost of such an operation may be as much as the permanent installation cost. Altering all of or part of the process flow for pilot test may not be possible. So a pilot test is extremely expensive and if the actual process stream is not used, the results may be meaningless. The drop size method, while not quite as expensive as a pilot test is labor intensive and costly. Often the two methods are combined. Although these latter two methods presently give the best predictive results when applied correctly, the costs associated with using such tests are prohibitive.

Thus the need has arisen for a simple and inexpensive system to predict, with some great degree of certainty, the operability of such hydrocyclone separators at a particular location.

It is therefore an object of the present invention to provide a new and improved method for forecasting the applicability of a hydrocyclone separation system to a particular set of operating characteristics.

Background of the Invention

With this and other objects in view, the present invention involves a technique for predicting the effectiveness of a separation process for separating one fluid phase from another in a fluid mixture under actual operating conditions. A representative sample is taken from the fluid mixture under the actual operating conditions at which a separation process would be operated to thereby provide a fluid sample having the same physical and chemical characteristics as well as having the same or nearly the same

concentrations, droplet size distribution, conditions of turbulence and shear, etc. The sample taken under these precise conditions is sometimes herein referred to as an isokinetic sample, i.e., having the same energy conditions. The sample or a portion thereof is placed in a centrifuge for a period of time at an RPM which will simulate the combined effect of expected centrifugal force and residence time which would be exerted on the mixture under normal operating conditions in a hydrocyclone. After the sample is thus centrifuged, a small portion is withdrawn from the portion of the centrifuge tube containing one of the separated phases of the fluid mixture and this small portion is then analyzed to determine the concentration of residual components of the other phase within the one withdrawn phase. This so determined concentration of residual components is then compared with the desired separation results under operating conditions.

Brief Description of the Drawings

Figure 1 is a schematic drawing of a portion of oil field separation process which might employ a hydrocyclone separator;

Figure 2 is a schematic representation of a sampling scheme for taking an isokinetic sample from a flowline;

Figure 3 is a schematic representation of an alternative sampling scheme for taking a representative sample from a flowline;

Figure 4 is a drawing depicting a centrifuge tube; and

Figure 5 is a graph plotting differential pressure against droplet shear.

Detailed Description of the Preferred Embodiments

The predictive technique described herein may be applied of course to any separation problem which requires a simple and inexpensive method to forecast the applicability of a hydrocyclone separator to such a specific separation situation. The invention is described herein with respect to the use of the technique as applied to the particular problem of determining the applicability of hydrocyclone separation technology to oily water separation which is

sometimes referred to as de-oiling. Figure 1 shows a schematic representation of portions of an oil production process and a de-oiling separation application for use of this technique. Hydrocarbon production from a well is taken from the wellhead at the surface into various treatment systems to separate the various fluid phases. A simple arrangement of such a system is shown in Figure 1 wherein produced fluids are delivered via a pipe 12 to a three phase separation device in the form of a residence vessel 14. A vent line 16 on the top side of the vessel 14 provides a means for entrained gas to be vented from the produced fluid mixture. An oil outlet line 17 is provided for recovering the separated oil phase from vessel 14. As the pressure of the mixture is reduced, and with the aid of gravity, separation takes the natural form of the heavier water and any solids 18 settling to the bottom of vessel 14. The layer of fluid shown at 22 is that of the incoming emulsion from the wellhead. The next layer 24 above the emulsion would be oil which is lighter than either the water or the produced stream. Lastly, a gas phase 26 would occupy the top layer as it comes out of solution from within the predominately liquid phases of the produced fluids.

For reasons set forth above in the Background of the Invention, it is often necessary to further separate the water phase in order that the water may be disposed of under environmentally acceptable conditions. It would, for such a reason, perhaps be desirable to further process the water phase through a hydrocyclone separation device such as shown represented schematically by dotted lines at 32 in Figure 1. Flow line 34 supplies an oily water phase under pressure from the residence vessel 14 to an inlet in the hydrocyclone. The less dense oil phase is represented as emerging from the hydrocyclone separator 32 at overflow outlet 36, whereas underflow outlet 38 is shown for passing the more dense water phase through a valve 42 to another separation device 44 for even further separation should that be necessary or desirable. For purposes of explaining the prediction technique, which is the subject of this

invention, the arrangement of Figure 1 is shown to provide the background for the need to use such a technique. The high cost associated with installing and testing such hydrocyclone separation devices makes it very desirable that some form of reliable predicting means be available to predetermine the economic viability of its use.

In the example situation described with respect to Figure 1, it is appropriate in the proper execution of the technique disclosed herein to first take a sample of the fluids to be separated at or near the exact location in the process where the device would be located. This would be at the location in Figure 1 where the dotted line representation 32 of a hydrocyclone is shown.

One of the sampling techniques in accordance with this invention is set forth in Figure 2 of the drawings wherein the flow line 34 is shown having a sample bomb 46 installed in a parallel diversion line 48 which is taken off the flowline 34. This arrangement would normally be installed as an assembly within an appropriate section of the flowline which would permit such an installation. The inlet to the sample bomb 46 has an inlet valve 50 installed in the diversion line 48. Likewise, the outlet side of the line 48 has an outlet valve 52 for opening and closing the outlet side of the line 48. An appropriate inlet to the line 48 is shown as a tube arranged to have its inlet end 54 centered within the flow line 34 so as to take an unsheared representative sample from the center of the flowline 34. The inlet and outlet line 48 to the sample bomb or housing 46 enters the housing at the bottom and exits through the top. Thus, as the sample is being taken, the flow of the sample, from the bottom to the top of the sample housing, maintains a good mixture of the sample, within the entire sample container. A gas bleed-off valve and line 51 are provided at the top of the sample bomb 46. A sample outlet valve and line 53 are provided on the bottom of the bomb. The problems associated with sampling in a flowline and shearing the sample in the sample taking process are outlined in detail in U.S. Patent 4,900,445 which deals with determining droplet size in

conjunction with pumping fluids into a hydrocyclone. The isokinetic sampling technique which is described in the aforementioned patent describes the type of sampling apparatus which would provide a sample meeting the needs of this prediction technique.

Referring again to Figure 2, the outlet side of the line 48 from the sample bomb passes through the valve 52 and back into the flow line 34 where it is arranged to discharge any effluent into the stream of flowline 34 from whence it came. The effect of the system shown in Figure 2 is to provide a means for being able to take a sample at the same velocity and under the same physical conditions as the flow stream being sampled. These physical conditions include but are not limited to pressure, temperature, viscosity, density and turbulence.

Our further testing of this system has shown, however, that other sampling techniques which minimize the effect of shear on the sampled fluids can also be used in this method. For example, samples taken with a non-shearing sampler having a 45° taper inlet, such as shown in Figure 3, also provide results which in the situations tested appear to provide good correlation with actual hydrocyclone use. This latter sharp edge arrangement involves a simpler physical setup in that only one entry point into the flowline 34 is needed to insert a sharp edge sampler tube 60 having a 45° tapered end portion 12 facing into the flow path of flowline 34. The sharp edge sampling tube is connected by means of an inlet valve 64 to diversion line 66 which enters the bottom of a sample bomb or housing 68. The sample bomb 68 has an outlet diversion line 70 leaving the top of the housing with an outlet valve 72. A valve 74 is also provided on the top of the sample bomb to provide for gas bleed-off. A sample taking outlet valve 73 may be provided at the bottom of the bomb. A vessel 71 is provided to catch flow through the sampler. This arrangement of lines in and out of the sample bomb provides for flow through the entire sampler housing to maintain a good mix of the sample.

In the operation of the sampling apparatus set forth above, after installing the sampling apparatus in the flow line 34, the valves arranged to pass fluids through the diversion lines, i.e. inlet valves 50, 64 and outlet valves 52, 72 are opened to provide for fluid flow through the sample bomb that is under the same flow conditions, including velocity and pressure, that exist within the flowline 34. By adjusting the valves, the flow can be regulated to provide a constant and representative stream through the bomb and at the same time minimize the differential pressure between the flowline and the sample bomb. Such a differential pressure drop will tend to shear droplets in the mixture which in turn will effect the results of the prediction technique. After flow through the sample bomb has taken place sufficiently to purge any fluids in the system and to establish representative fluid flow through the sample bomb, the inlet valve 50, 64 is closed and then the outlet valve 52, 72 is also closed to isolate the sample in the bomb. A gas bleed-off valve 51,74 is then opened to bleed-off any gas pressure in a controlled manner before the sample is centrifuged. This bleed-off step tends to provide a distortion in the prediction procedure in that as soon as you drop the pressure in the sampler, the larger droplets will start to break out of solution and pass up through the sample. This may tend to skew the measure of droplet distribution in that the sample will contain smaller droplets out of proportion to that in the flowline. On the other hand, the larger droplets are known to separate readily in the hydrocyclone so as not to really affect the predictive quality of the technique. It is emphasized that the above sample taking and bleed-off are an important step in this technique in that if done properly it will minimize distortion and lead to a reliable predictive procedure. Thus the flow is set up through the sample bomb to be representative of pressure and velocity in the flowline and after sample isolation, pressure bleed-off is to be done slowly so as to distort droplet distribution as little as possible. At the same time, the overall time frame of the procedure should be compressed to

minimize the effects of gravity separation. The point of all this is to take a representative fluid sample at a relatively high pressure in the flowline and drop the pressure to atmospheric pressure for centrifuging, while generating minimum shear and gravity separation of droplets in the mixture.

Figure 5 shows a graphical representation of the effect of pressure drop on droplet shear. If you plot pressure drop versus percent of shear that takes place in a pump, valve, sample tap, or the like, such as is involved in the sampling and gas bleed-off procedure, what occurs is that at very low or no delta P the shear ratio, i.e., mean droplet size out over mean droplet size in, is 1, thus there is no shear. As you increase the differential pressure at some pressure drop point in the system, the mean drop size out becomes smaller because the droplets are shearing and the ratio becomes less than one and the percent of shear increases to a point on the chart where percent of shear increases to 80% and levels out. This plot emphasizes the need to minimize differential pressure in the system by making changes in flow settings or operating valves in a gentle manner to let equalization take place at a moderate rate.

Once the sample is isolated and pressure is bled off, an outlet line and valve 53, 73 is opened to transfer a portion of the sample to centrifuge tubes as shown at 76 in Figure 4. A long syringe needle 84 is then placed in each tube before centrifugation. This is to prevent disturbing the mixture after it is centrifuged by inserting a syringe needle through free oil forming a top layer 78 in the centrifuged mixture. The centrifuge tube or tubes are then placed in the centrifuge where they are centrifuged at an RPM and a period of time that will simulate the combined effect of centrifugal force and residence time under actual hydrocyclone conditions. It has been found that a number of combinations of RPM and centrifuge times will provide the desired results. One such combination is 500 RPM for 90 seconds. After centrifuging, a glass syringe (not shown) is attached to the syringe needle 84 and a sample (for example 50 ml) is withdrawn

from the lower water phase portion 80 in the centrifuge tube. This sample is taken above any solids 82 which may collect in the bottom of the tube. The sample thus withdrawn is then analyzed to determine the parts per million of oil in the water phase 80. This will predict the expected separation efficiency of a hydrocyclone placed in the flow line at the same location.

The centrifuge test which is the basis of the predictive technique of this disclosure has as its main advantage the use of a centrifuge, an infrared oil-in-water analyzer, and simple devices to ensure proper sampling. All of these are either present in most oil fields or can be easily provided. The assumptions made in designing the technique have, it will be shown, held up very well in practice.

The rationale behind this technique is based on Stoke's Law, which predicts the rate of movement due to a force field (gravitational, electromagnetic, centrifugal, etc.) of a spherical droplet in a fluid of different density.

Stoke's Law is given as follows:

$$v = \frac{f \, \Delta\rho D^2}{\mu}$$

where v is the velocity of the droplet through the fluid (cm/sec), f is the acceleration due to the force field (cm/sec^2), $\Delta\rho$ is the difference in density between the two fluids, i.e. oil and water (g/cm^3), D is the diameter of the droplet (cm), and μ is the viscosity (poise) of the fluid through which the droplet moves, which is water in the case of a de-oiling hydrocyclone.

It can be seen from Stoke's Law that the movement of an oil droplet through water is a quadratic function of the diameter of the droplet; i.e., large droplets separate much faster than small ones. It should also be noted that there are only three other pertinent variables. For two of them, the strength of the force field and the density difference between the oil and water, high values mean better separation. The viscosity of the water, in the case of a de-oiling hydrocyclone, we want to be low. Typically the water phase of oil

field production is brine. Both density difference and water viscosity are, of course, functions of temperature. In general, higher temperatures mean better separation rates.

In a centrifuge as well as in a hydrocyclone, the principal force acting on an oil droplet suspended in brine is the centrifugal force. This is provided by the rotational motion of the centrifuge and by the helical movement of the fluid in a hydrocyclone. The radial distance traveled by a droplet in either device is given by

$$d = vt,$$

where d is the distance (cm), v is velocity and t (sec) is the time of travel.

The centrifugal force experienced by an oil droplet in a hydrocyclone and the droplet's residence time in the device can be calculated. It has been found in the development of this prediction technique that a centrifuge can be adjusted so that the combined effect of these two parameters, centrifugal force and residence time, are the same (or nearly the same) as in a hydrocyclone. If this is done, then the percentage of droplets removed and coalesced in the two devices is approximately the same or at least linearly related. One needs only ensure that the water temperature (hence its viscosity and the oil-water density difference) and the droplet-size distribution are the same in the centrifuge test as in the proposed hydrocyclone application. In other words, the test is so designed that all the pertinent variables will be, as closely as possible, reproduced in a hydrocyclone and in a centrifuge test for the same produced water. Therefore, a key to the success of this technique is providing a test sample which is representative of actual operating conditions.

Centrifugal force, commonly expressed in multiples of the standard force of gravity, varies with the rotational speed and with the radial distance from the center of rotation. At the wall of a bowl of diameter D_b, the centrifugal force is given by:

$$F_c = 0.0000142\ n^2\ D_B$$

where F_c is the centrifugal force (multiples of gravity), n is the

speed of rotation (rpm) and D_b is the bowl diameter (inches). A bowl diameter is defined as the distance between the ends of opposing centrifuge tubes in their horizontal position.

Oil-droplet size distribution is known (by Stoke's Law) to play the dominant role in determining the effectiveness of any gravity-separation device, such as a centrifuge or hydrocyclone. Drop-size distribution is the variable most often cited to explain why a hydrocyclone does or does not work for a given oily-water source, but as was discovered in tests of this technique in field conditions, droplet-size alone might be a seriously erroneous predictor of hydrocyclone performance.

The effect of droplet-size distribution on the performance of the centrifuge and of the hydrocyclone should, by design of the centrifuge technique, be nearly identical. Therefore, droplet size distribution is not expected to affect the correlation between test result and hydrocyclone oil-removal efficiency.

The centrifuge test has proved to be a remarkably good predictor of hydrocyclone performance, even in an exceptional case where data was taken from an oil well whose "peculiarities" included an atypical drop-size distribution, low temperature and consequent high water viscosity, and a low density difference between the oil and the water. Any of these, taken singly or together, would alert a potential hydrocyclone user to possibly non-applicability. The centrifuge test tied all the parameters together to come up with a prediction of hydrocyclone performance which was quite close to being correct.

Tests were made on several oil well leases to verify the centrifuge test and to substantiate its use as a predictor for hydrocyclone performance. In the first test a low shear pump (twin-lobe) was used at the lease, not only to produce different hydrocyclone operating conditions, but to create a range of oil droplet sizes. The range of mean droplet sizes were varied from 10 to 20 microns. With a specially designed separator, a wide range of

inlet oil concentrations were tested. The hydrocyclone flow rate was from 744 to 1183 barrels per day (BPD) with a reject ratio of 1.6 to 2.2 percent. The reject ratio is the ratio of separated, less dense fluid to the more dense fluid. The flowing fluid temperature was 48°C, and the specific gravity difference between the produced water and crude was 0.171. The inlet oil concentration ranged from 274 to 608 ppm. The outlet oil concentration was from 63 to 165 ppm. In this test, the centrifuge test data indicated that produced water passed through a twin-lobe pump would not be a good candidate for use of hydrocyclone technology. Substitution of a low-shear Moyno pump resulted in a produced water with larger oil droplet sizes. Tests later proved that the water was hydrocyclone-treatable when steps were taken to avoid shearing the oil droplets. It is important to note that as in this test, intermediate values of the oil content of the centrifuged water may indicate that some modification of lease operation would be necessary to improve the "treatability" of the produced water. For example, the data from this lease suggested that it was not a candidate for hydrocyclone. However, when a low-shear Moyno pump was substituted for a twin-lobe pump, the hydrocyclone gave satisfactory results at this lease.

In another test a much cooler flowing fluid temperature (15°C) and a narrower range of oil droplet size (11.17 to 13.83) were encountered. The hydrocyclone flow rate ranged from 902 to 1437 BPD, while the reject ratio was from 1.5 to 2.4 percent. The specific gravity difference between the two fluids was 0.117. The inlet oil concentration varied from 215 to 355 ppm. The outlet oil concentration was from 142 to 229 ppm. This lease provided an exceptionally uniform droplet-size distribution for the produced water. The poor hydrocyclone performance at this site is almost certainly due to the large volume of oil droplets smaller than 10 microns diameter, to the cooler fluid temperature and resulting high water viscosity, and to the relatively low density difference between the oil and the water. The centrifuge test data correctly indicated

that this site would not be a good candidate for use of hydrocyclone technology. Hydrocyclone test data confirmed this observation.

A total of 10 runs were made on another well. The hydrocyclone flow rate varied from 662 to 1042 BPD, and the reject ratio was from 1.62 to 3.53 percent. The fluid temperature was 69°C, and the specific gravity difference between the produced water and the crude was 0.235. Inlet oil droplet size ranged from 9.08 to 15.77 microns. The inlet oil concentration was from 56 to 135 ppm. The outlet oil concentration was a very narrow band from 21 to 46 ppm. The hydrocyclone performed much better at this well than would have been expected from the low (10 micron) median oil droplet size. Previous results with such small droplet sizes showed lower oil removal efficiencies. Two possible factors that may have contributed to the improved performance are the higher produced fluid temperatures and the larger density differences between the crude and the produced water. However, the important point is that the centrifuge test correctly predicted that this well would be an excellent candidate for use of hydrocyclone technology, whereas in this situation droplet size analysis and oil concentrations alone would not have done so without further extensive testing.

The above cited tests provided a clear correlation between the centrifuge technique and the actual operation of a hydrocyclone, whereas earlier attempts to analyze the various variables in operating conditions proved unworkable for predicting applicability of a hydrocyclone. This is because the number of such variables is actually very large, as those skilled in the art will appreciate. Consequently, rather than trying to analyze such conditions to make a prediction, the present technique provides a simple method to give a very accurate prediction based on a simple, inexpensive and quick test that provides a surprisingly accurate simulation of hydrocyclone performance.

In yet another aspect of this invention, a modification in the above described procedure finds use in providing a method to not

only predict the viability of the hydrocyclone separation but additionally on the effect of separation altering agents in any additional separation system to be employed in a separation process. In this respect, chemicals can be injected into the fluid mixture upstream of the sample taking procedure to provide a further method for predicting the effect that chemicals will have on the separation process. With respect to the processes disclosed herein, tests have shown that the addition of certain chemicals will enhance coalescing of oil droplets in an oil/liquid mixture. The predictive technique described herein has been used to predict the effect various chemicals will have on such enhancement. In this regard it is important that any candidate chemical be tested under the actual operating conditions that would be incurred in a commercial separation process. This can be accomplished by injecting a candidate chemical into the flowstream (see Figure 1) by means of a chemical supply and injection apparatus 15 which is arranged in the flowline 34 upstream of the sampling point. The chemicals can be injected by a pump or through gravity methods as is needed. In still another aspect of the predictive technique, the chemicals or such separation modification agent can be injected into the sample as by introducing directly into the centrifuge tube prior to centrifuging of the sample. The agent is then mixed with the sample as by shaking the centrifuge tube gently. While the chemical or agent is not subjected to the flow conditions of the actual separation process, the agent is subjected to the fluid to be separated under the actual physical and chemical conditions of the mixture in the operating environment. What is significant about injecting the agent directly into the sample in the centrifuge tube is that the operating system is not contaminated by traces of the agent being tested and as is usually the case a number of different treating agents can be tested to compare the effect on the separation process by injecting the agent into separate samples in separate centrifuge tubes. These additional techniques can therefore be used for

screening of various chemicals and selecting those which could be subsequently used for enhancing performance in separation technology.

This invention has been shown herein as having application to oil field oil/water separation. It is readily seen that other separation processes involving the use of a hydrocyclone or other such separation systems would also find use with this technique. Therefore, while particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I CLAIM:

Claim 1. A method for predicting the performance of a hydrocyclone separator in a process for separating one phase from at least one other phase in a fluid mixture under actual operating conditions, wherein the separated phases will contain residual components of the other phase in the one phase, including the steps of;

obtaining a fluid sample representative of the energy conditions of the fluid feedstream to be separated, which sample is to be taken under the actual operating conditions at which the hydrocyclone would be employed to separate the fluid phases in the feedstream;

placing the sample in a centrifuge tube;

centrifuging the sample for a sufficient time period and at a sufficient RPM to approximate the expected combined effect of centrifugal force and residence time which would be exerted on the mixture under normal operating conditions in the hydrocyclone;

withdrawing a portion of the centrifuged sample from the portion of the centrifuge tube containing one of the separated phases;

determining the concentration of the residual component of the other phase in the one withdrawn phase, and

comparing the determined concentration with the desired separation results under actual hydrocyclone operating conditions.

Claim 2. The method of claim 1 and further including obtaining an isokinetic sample of the fluid mixture to be separated.

Claim 3. The method of claim 1 wherein the fluid mixture to be separated includes a hydrocarbon phase and a water phase and further including taking an isokinetic sample of the fluid mixture substantially at the location in the process where the separation is to occur.

Claim 4. The method of claim 1 and further including prior to centrifuging the sample, determining the combined effect of centrifugal force and residence time that the feedstream fluid mixture would be subjected to under the actual hydrocyclone operating conditions; and

operating the centrifuge so that the effect of centrifugal force and residence time in the centrifuge is substantially the same as in the actual hydrocyclone separation process.

Claim 5. The method of claim 1 and further including injecting a separation enhancing chemical into the sample and mixing the injected sample with the chemical prior to centrifuging the sample, and

after determining the concentration of the other phase in the one withdrawn phase, comparing this determined concentration with desired separation results to determine the effect of the injected chemical on the separation process if it were carried out in a separation process using hydrocyclone technology.

Claim 6. A method for predicting the viability of separating fluid phases from a fluid mixture by means of a hydrocyclone when the hydrocyclone is installed in a production flowline comprising the steps of;

providing a sampling location within the production flowline for taking representative samples of fluids in the flowline under actual operating conditions within the flowline;

isolating a sample of the flowline fluids under the energy conditions of the fluids in the flowline;

bringing the fluids in the isolated sample to atmospheric pressure conditions in a manner to minimize disturbance of droplet size distribution within the mixture;

centrifuging a representative portion of the sample at an RPM and for a time period which together provide a simulation of the combined effect of centrifugal force and residence time which such fluid mixture would be subjected to in a hydrocyclone;

withdrawing a portion of at least one phase of the centrifuged mixture; and

analyzing the portion of at least one phase of the mixture to determine the concentration of at least one residual component of at least one other phase in the one phase of the mixture to predict the

separation efficiency of a hydrocyclone operating in the flowstream at the sampling location.

Claim 7. The method of claim 6 and further including comparing the concentration of the at least one other phase in the one phase with a desired concentration of fluid phases in the fluids to be separated to determine the viability of utilizing a hydrocyclone to separate the fluid mixture under the specific conditions present at the sampling location.

Claim 8. The method of claim 6 and further including introducing a proposed separation modifying agent into the sample prior to centrifugation of the representative portion, and after analyzing the mixture for concentration of one other phase in the one phase, comparing the determined concentration with desired phase concentration parameters in the mixture to determine the effect of the modifying agent on desired separation parameters.

Claim 9. The method of claim 6 and further including injecting a separation modifying agent into the fluid mixture prior to centrifugation of a portion of the sample to determine the effect of a particular modifying agent on the separation process.

Claim 10. The method of claim 6 and further wherein the taking of a sample from the flowline includes passing the sampled fluid into the bottom portion of a sampling container and out of the top portion of the sampling container to provide for mixing of the fluid in the sample container prior to isolating the sample of fluids.

Claim 11. A method for predicting separation efficiency in a hydrocyclone separating process for separating liquid components from a fluid mixture comprising the steps of;

providing a sampling location within a production flowline for taking samples of a fluid mixture from the flowline;

isolating a sample of the flowline fluids under the conditions of the fluids in the flowline;

bringing the fluids in the isolated sample to atmospheric pressure conditions in a manner to minimize disturbance of droplet size distribution within the fluid mixture;

introducing a separation modifying agent into the sample;

mixing the separation modifying agent into the components of the fluid mixture;

centrifuging a representative portion of the sample containing the separation modifying agent at an RPM and for a time period which together provide a simulation of the combined effect of centrifugal force and residence time which the fluid mixture would be subjected to in a separation process incorporating hydrocyclone technology to provide separated liquid components;

withdrawing a portion of at least one separated component of the centrifuged mixture to determine the concentration of at least one other separated component remaining in the one separated component to predict separation performance using the separation modifying agent.

Claim 12. The method of claim 11 and further wherein the taking of a sample from the flowline includes passing the sampled fluid into the bottom portion of a sampling container and out of the top portion of the sampling container to provide for mixing of the fluid in the sample container prior to isolating the sample of fluids.

Claim 13. A method for predicting the performance of a separation system in a process for separating one phase from at least one other phase in a fluid mixture containing droplets, under actual operating conditions, wherein the separated phases will contain residual components of the other phase in the one phase, including the steps of;

providing a sampling location within a process flowline for diverting a sample stream of the fluid mixture in the flowline under the actual energy conditions of the fluids in the flowline into an enclosable chamber;

introducing a proposed separation modifying agent into the sample prior to isolating a sample from the flowline;

isolating a sample of the flowline fluids by diverting the flowline fluids through an enclosable chamber;

enclosing the flowline fluids in the enclosable chamber by closing upstream and downstream valves on the chamber so that the pressure drop resulting from the enclosing of the fluids occurs at the downstream side of the enclosed fluids;

bring the fluids in the isolated sample to atmospheric pressure conditions in a manner to minimize shearing of droplets within the fluid mixture;

permitting separation of the phases within the fluid mixture sample for a time period and under physical conditions which together approximate the expected effect of the separation system on the process; and

determining the concentration of at least one residual component of one phase within at least one other phase of the mixture; and

comparing the determined concentration with available separation data to determine the effect of the proposed modifying agent on the separation system performance.

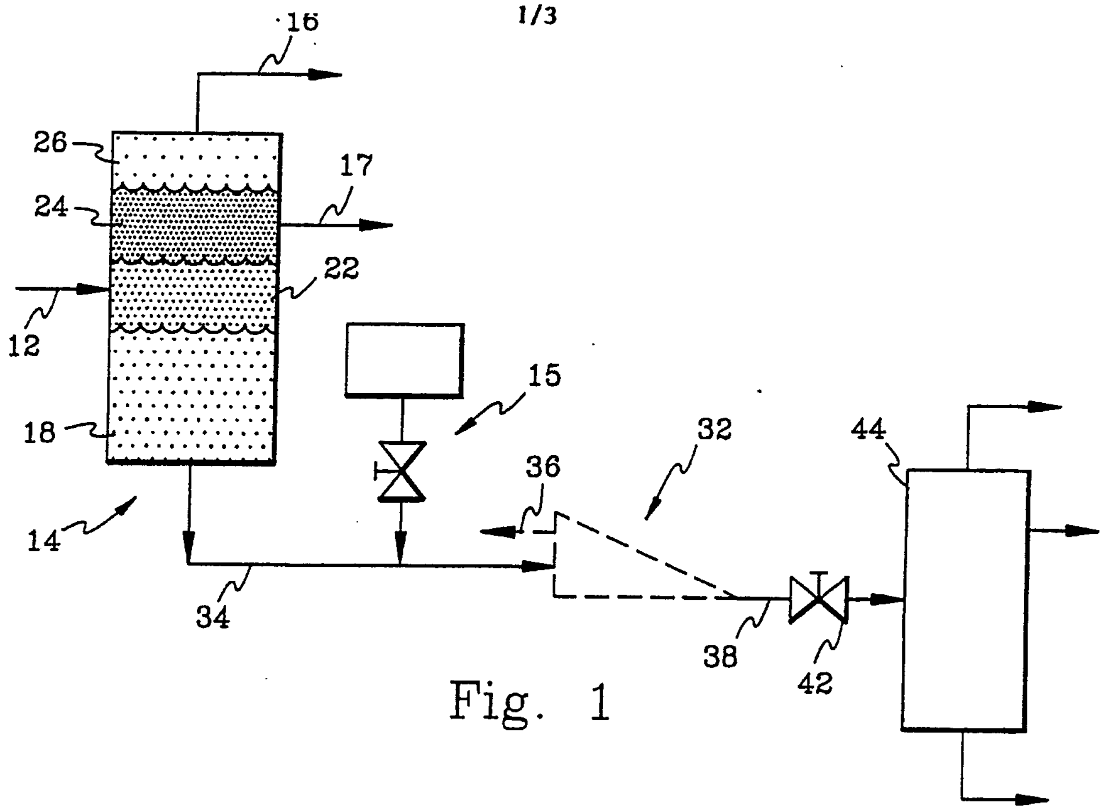

Fig. 1

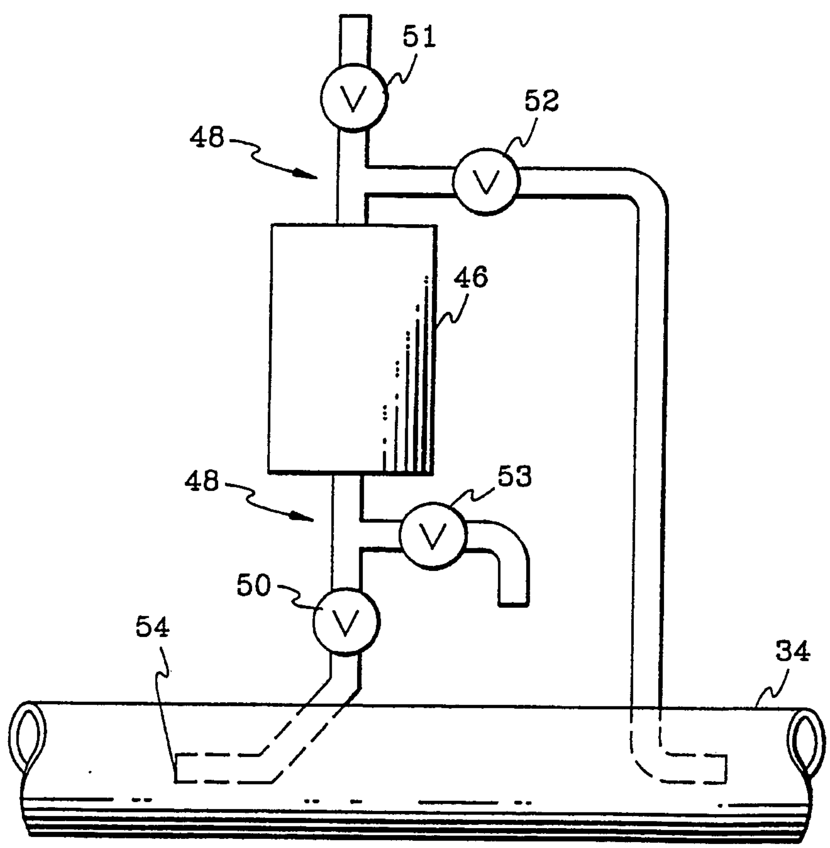

Fig. 2

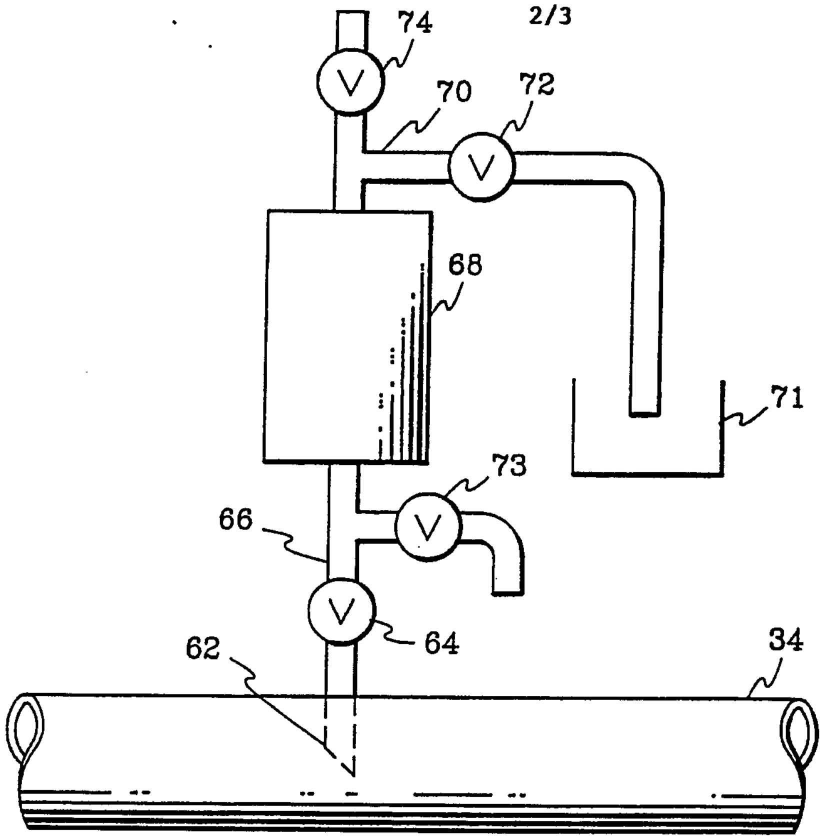

Fig. 3

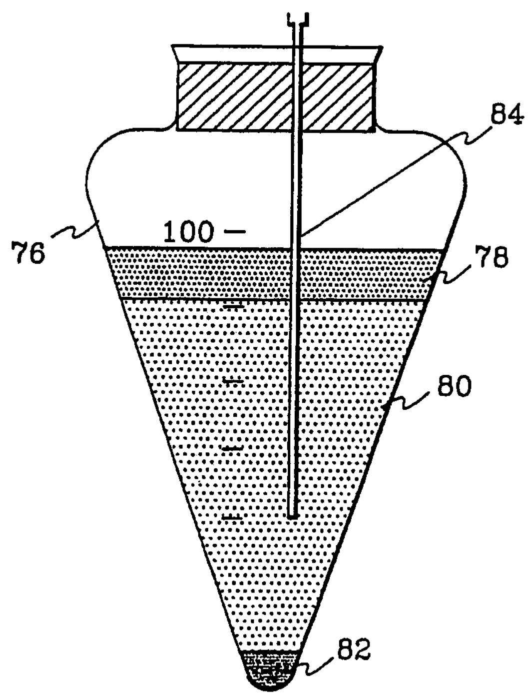

Fig. 4

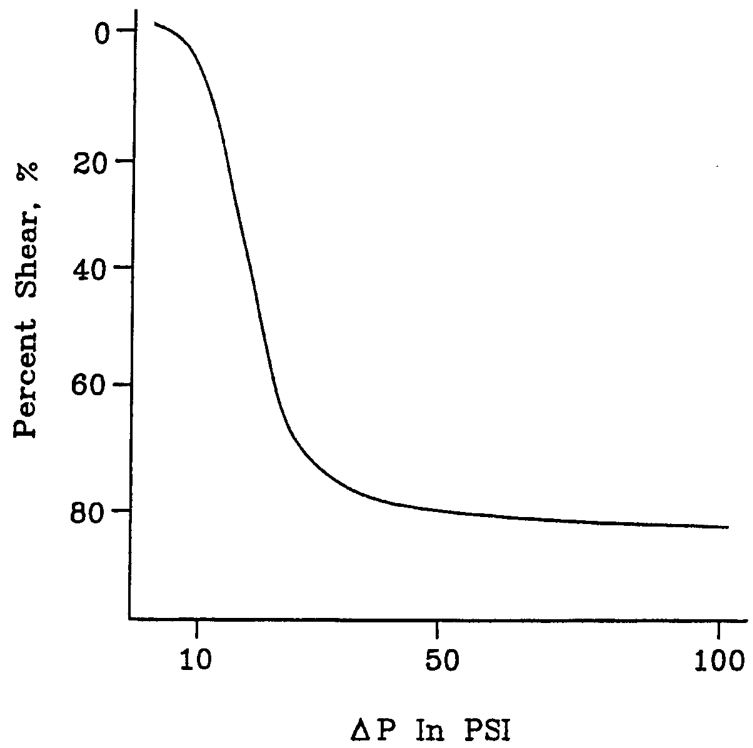

Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/02156

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): B01D 21/26

U.S. CL: 55/270, 73/61.1R, 61.4, 863.03, 863.21, 209/1, 210/787

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S. CL.	55/270, 73/1DC, 61R, 61.1R, 61.4, 863.03, 863.21, 863.31 209/1,144,211 210/512.1,787

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X A	US, A, 4,900,445 FLANIGAN ET AL. 13 February 1990 (see entire document)	13 1-12
Y A	US, A, 4,844,817 FLANIGAN ET AL. 04 July 1989 (see entire document)	13 1-12
Y	US, A, 3,869,903 BEACH ET AL 11 March 1975 (see entire document)	13
Y	US, A, 3,812,966 BEACH ET AL 28 May 1974 (see entire document)	13
A	US, A, 4,815,536 PRENDERGAST ET AL 28 March 1989	1-12
A	US, A, 4,479,379 TARCY 30 October 1984	1-12
A	US, A, 4,426,880 WALTERS ET AL 24 January 1984	1-12
A	US, A, 4,413,533 DIESEL 08 November 1983	1-12
A	US, A, 1,649,399 GARD 15 November 1927	1-12

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
19 JUNE 1990	06 FEB 1991
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	Veronica Wise for JOSEPH W. DRODGE

Form PCT/ISA/210 (second sheet) (May 1986)